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Work in Progress: Cultivating Reflective Engineers: Does providing a reflective ePortfolio experience in a first-year design course lead students to be more reflective in later courses?

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Introduction

This work in progress paper assesses whether a first-year ePortfolio experience promotes better reflection in subsequent engineering courses. While reflection is vital to promote learning, historically, reflection receives less attention in engineering education when compared to other fields [1]. Yet, cultivating more reflective engineers yields several important benefits including building self-efficacy and empowering student agency. Through continued practice, engineering students can develop a habit of reflective thinking which increases students' ability to transfer knowledge across contexts. The adoption of ePortfolios is becoming an increasingly popular strategy to improve student learning and establish a culture of reflection.

The Department of Electrical and Computer Engineering at a small liberal arts college in the northeastern United States is beginning to incorporate ePortfolios into courses. Professors of a first-year design course developed an ePortfolio assignment that gives students a space to reflect on their potential career paths and envision themselves as future engineers. We were curious about the impact this experience might have on students' reflective thinking as they continue through the program. This work was guided by the research question: *Do student ePortfolios in a first-year design course promote better reflection in subsequent technical courses?* In this paper, we investigate this question by coding instances of reflection in student lab reports from a second-year design course. As a control group, lab reports from students the previous year who had not completed the ePortfolio activity were compared. We provide a quantitative summary of our analysis which concludes students that were provided with a reflective ePortfolio experience in their first-year are more reflective thinkers in their second-year.

Literature Review

Reflection has been recognized as a critical component of learning since the early 20th century. Education researchers championed "reflective thought" as a form of problem-solving [2] and a process of confronting one's own confusion and ambiguities through "naming" and "framing" their struggle [3]. Reflection is a practice that externalizes thought, making thinking visible so that new knowledge can be integrated with existing knowledge [4]. Although reflection has largely been used as a tool for developing writing skills, contemporary research has explored its contributions to other disciplines, including professional occupations such as nursing [5], teaching [6] and engineering [7].

Reflection is often used by faculty as a tool to assess what students have learned; however, it has much broader potential. First, reflection is an important tool for facilitating knowledge transfer across contexts. Reflective activities stimulate metacognition, a process wherein students articulate how they learn and develop strategies for future learning [8]. Students who reflect on their learning are more able to make connections between the knowledge acquired across multiple courses, retain information they have learned, and extend this knowledge into new contexts and domains [9], [10].

A second benefit of reflection is to help students build self-efficacy and positive identities. Studies have shown that ePortfolio assignments can have a positive impact on students' motivation to learn, including self-efficacy, autonomy, and sense of belonging in the classroom [11]–[14]. For our purposes in engineering education, we hope ePortfolios will help students begin to identify as future engineers and thoughtfully integrate their whole selves into their engineering identity.

Thirdly, reflection offers potential for improving student support. Many challenges students face in college are factors unrelated to their academics, such as personal relationships, financial resources, etc. Reflection activities designed to encourage students to consider the impacts of personal issues on their learning help bring these concerns to the attention of professors and/or support staff, who may be able to offer assistance or accommodations [15].

Finally, reflection empowers students to be active agents in the world. Yancey [4] has argued that reflection is a tool for becoming co-creators of society. Through these assignments, we empower students to see engineering as a field over which they have some influence, to develop a vision for our future society, and to recognize that by their action they can remake the world.

ePortfolios have become more prevalent in higher education as a tool to encourage student reflection across all aspects of their lives [16]–[18]. A campus-level platform allows universities to support and integrate reflection at different levels: individual course assignments, curriculum-wide reflection, and inclusion of other university experiences, such as athletics, career services, and student organizations. This multilevel integration is crucial for achieving the full benefits of reflection in education [19]. The use of digital platforms may enable new kinds of reflective thinking [20] as students creatively curate different media types, including text, images, video, concept maps, and social media. Students develop their ability to integrate a variety of experiences and types of knowledge acquired at the university, synthesizing and sense-making through the construction of these centerpieces.

There are several existing tools that evaluate students' reflective capabilities [21], [22]. Hatton and Smith's [6] widely-cited tool identifies four categories of reflective writing. *Descriptive Writing* is not reflective, but simply reports events and literature. *Descriptive Reflection* is an explanation of students' rationale based on their personal judgment or evaluation of the literature. *Dialogic Reflection* is a discourse with one's self, an exploration of personal logic and rationale. Finally, *Critical Reflection* involves giving a reason for decisions or events that relates to broader historical, social or political contexts. Hatton and Smith caution that these levels are not necessarily hierarchical as different contexts may require reflection at different levels [6]. However, there does appear to be a developmental sequence in which students acquire reflective ability by building upon lower levels.

Our department is experimenting with incorporating ePortfolios into several of our courses, including our first-year design course. Faculty teaching second-year courses anecdotally observed that the cohort of students who completed ePortfolios were noticeably more reflective in their lab reports, which prompted this investigation into the impact of the first-year ePortfolio assignment. We wished to determine if there was a substantial difference in the reflective quality of reports submitted by students who had completed the ePortfolio assignment and those who had not.

Methods

To explore this question, we compared second-year lab reports from two cohorts of students. Students who plan to graduate in the Class of 2024 did not create ePortfolios in their first-year design course. This cohort will hereafter be called the “Control Cohort”. Students who plan to graduate in the Class of 2025 created ePortfolios in the first-year design course, hereafter referred to as the “Experimental Cohort”.

All classes took place at a small liberal arts college in the northeastern United States. Lab reports were collected from a second-year design course for both the Control and Experimental cohorts. Our cohort size is small as only about half the students from each class year take this course each semester and the maximum number of students per class year is capped at 35. Demographic information for both Cohorts is shown in Table 1.

Table 1. Demographics of Student Cohorts

	Control Cohort	Experimental Cohort
Cohort Size (N)	7	14
Men	4	12
Women	2	2
Nonbinary	1	0
White	6	12
Students of Color	1	2

Students in the course complete weekly lab reports to document their work building an IoT device. These lab reports typically have seven sections, which are prompted by the instructor: Objective, Describe Your Work, Results, Reflection and Context, Muddiest Points, Summary, and Citations. Students often include photos of their works-in-progress in the body of the report, but the number of photos is not prescribed. There is no page limit for the report; total page length varies by student, but ranges from 2 to 9 pages.

Reflection is a subjective term, which is likely to take on different meanings in different contexts. In discussions amongst the co-authors of this paper, each person defined reflection differently: the length of the sections, discussion of the student’s emotions during the assignment, and level of detail included in the description were all considered as potential markers of reflection. The established metrics for reflection [6] are typically developed for writing assignments in social science and humanities courses, not engineering lab reports, and thus did not perfectly fit our context in engineering. Curious to see how engineering reflection assignments might differ from those in other disciplines, we used inductive methods to help us identify what faculty members characterized as evidence of reflective thinking in this particular assignment and compare those observations to established education literature.

Our research team began with an inductive review of a small sample of lab reports from both cohorts, Control and Experimental. Inductive methods are a useful tool for eliciting cultural meanings within groups to ascertain what is meant in a particular community when subjective terms such as "reflection" are used [23], [24]. During First Cycle coding, we followed recommended protocols for Descriptive Coding [25], reading each lab report together as a team and describing what we thought indicated evidence of reflective thinking. Each suggestion was debated amongst the group and, if agreed upon, a code was generated and added to the codebook. Next, we sorted our code list according to Hatton and Smith's [6] four types of reflection: *Descriptive Writing* (Not Reflective), *Descriptive Reflection*, *Dialogic Reflection*, and *Critical Reflection*. This linkage of our inductive categories to an established method helped us evaluate the overall quality of students' reflective abilities. Our codebook and examples of each code can be found in Appendix A.

Once the codebook was generated, all lab reports (N=21) were coded using NVivo qualitative data analysis software. Two members of the team independently coded each report and met regularly to compare codes. Points of difference were discussed and resolved per consensus coding techniques [26], [27]. These efforts contributed to intercoder reliability, reducing the risk of individual bias [28].

Quantifying qualitative data is another place in which subjective decision-making takes place. To summarize our data numerically, we decided to count all code references in each report, rather than counting only one instance of each code per report. This method gave students credit if they had multiple instances of the same code in their report, which we felt indicated more consistent reflection. The numerical data were adjusted to correct for the difference in number of students per cohort.

Results

Our results indicate the lab reports from the second-year students that completed the ePortfolio assignment are more comprehensive and demonstrate more frequent and varied reflection when compared to the students who did not create an ePortfolio in their first-year design course. As shown in Table 2, the total average report length increased by more than a page while the overall average number of codes per report increased by 88.9% between the Control and Experimental Cohorts. The largest number of codes referenced for any single report was 24 codes in the Experimental Cohort compared to the maximum of only 8 code references found within the Control Cohort. As shown in Appendix A, our final codebook contained a total of 14 codes. Instances of only 11 of our 14 codes were identified in reports of students in the Control Cohort while evidence of all 14 of our identified codes were found in the reports from the Experimental Cohort.

We further analyzed the student reports by observing the trends between our two cohorts based upon the four categories of reflective writing developed by Hatton and Smith. We found that each reflection category appeared in the Experimental Cohort reports with greater or the same average frequency exhibited by the Control Cohort as detailed in Table 3. *Dialogic Reflection* occurred most commonly among both cohorts and also accounted for the greatest number of codes encompassing half of all the codes identified in our codebook. The category that was least prevalent among all student reports was *Descriptive Reflection* with only two individual instances identified within all of the Control Cohort's reports. The frequency of *Descriptive Reflection* exhibited the largest percentage increase between the two studied cohorts, however the limited number of instances in the Control Cohort may have over-inflated this result. The frequency with which *Dialogic Reflection* was coded increased significantly for the Experimental Cohort while we were surprised to find the frequency of *Critical Reflection* remained the same.

Table 2. Page Length and Code Frequency by Cohort

	Range		Average	
	Control Cohort	Experimental Cohort	Control Cohort	Experimental Cohort
Report Length	2-6 pages	2-9 pages	4.00 pages	5.21 pages
Number of Codes	2-8 codes	5-24 codes	5.14 codes	9.71 codes

Table 3. Frequency of Reflection Types by Cohort

	Range of Codes		Average number of Codes	
	Control Cohort	Experimental Cohort	Control Cohort	Experimental Cohort
Descriptive Writing Codes	0-2	0-3	1.14	1.64
Descriptive Reflection Codes	0-1	0-4	0.29	1.00
Dialogic Reflection Codes	0-4	1-11	1.86	4.86
Critical Reflection Codes	1-3	0-4	1.57	1.57

Descriptive Writing and *Descriptive Reflection* code instances are combined in Figure 1. *Descriptive Writing* is the type of writing that Hatton describes as not being reflective but reporting events and processes. "Learned a Skill" is the only *Descriptive Writing* code we included in our code book. Most of the reports demonstrated at least one instance of *Descriptive Writing* while there was one report in each of the cohorts where no instances were coded. Reports in the Experimental Cohort tended to use the "Learned a Skill" code more often in their writing than the Control Cohort. The percentage of all students that included either a single or no instances of this code were 62.5% (5 of 8 students) for the Control Cohort and 42.9% (6 of 14 students) in the Experimental Cohort.

Two codes for our codebook were identified as *Descriptive Reflection*. One of these codes, "Evidence of Iteration or Non-required Work", was 1 of the 3 codes that did not appear in any reports from the Control Cohort. Five instances of this code were identified in the Experimental Cohort and were used when students described going above what was assigned in terms of correcting issues with their work or reporting that skills were practiced before attempting the required work (See Appendix A). The other *Descriptive Reflection* code, "Evaluative Description about Work and Environment", appeared only twice among all the Control Cohort reports but with more than double the frequency in the Experimental Cohort reports. The Experimental Cohort was also more thorough when using this code, sometimes using 3 or 4 sentences in the coded instances while the Control Cohort reflections generally consisted of only 1 or 2 sentences.

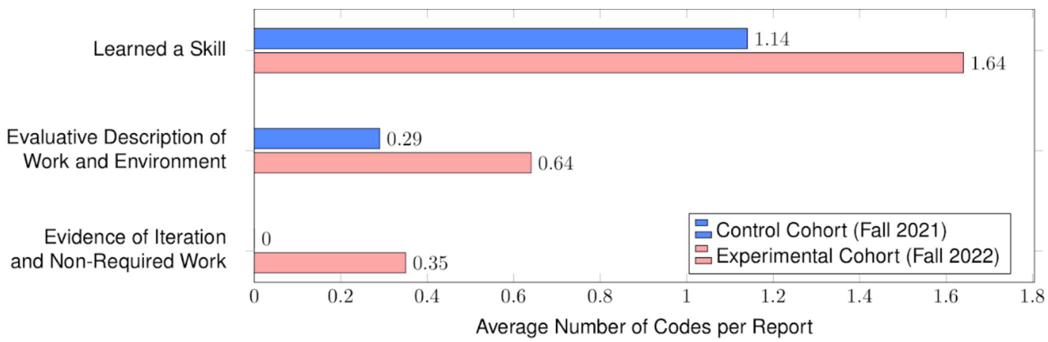

Figure 1: Comparing Control and Experimental Cohorts for codes categorized as *Descriptive Writing* or *Descriptive Reflection*

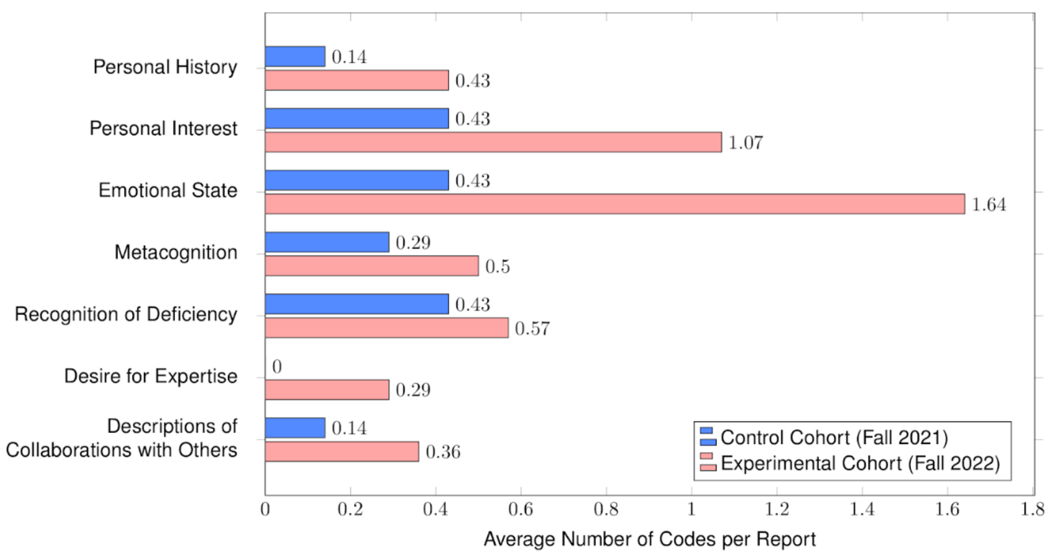

Figure 2: *Dialogic Reflection* codes frequency comparison for the Control and Experimental Cohorts

The adjusted frequency for each of the seven identified *Dialogic Reflection* codes increased for the Experimental Cohort as seen in Figure 2. "Recognition of Deficiency" was the code that showed the most modest improvement with a 33.3% increase between the two cohorts. The *Dialogic Reflection* coded most frequently in the Experimental Cohort reports was "Emotional State" with on average more than one instance of this code being identified in each report. Students in the Control Cohort wrote about their emotions by using the words confident, fun and enjoyable. Students in the Experimental Cohort reported a wider range of emotional states adding feelings such as appreciation, frustration, being comfortable and feeling overwhelmed.

The Experimental Cohort also exhibited more personal reflection shown by the significant increase in usage of both the “Personal History” and “Personal Interest” codes. Finally, the Experimental Cohort reports offered more varied reflection utilizing the “Desire for Expertise” code a few times when this code was not found in the reports of the Control Cohort.

As shown in Figure 3, the *Critical Reflection* codes are the only category where we did not observe more frequent use by the Experimental Cohort. When combining the four *Critical Reflection* codes, we found no difference in frequency between the two cohorts’ use of *Critical Reflection*. In fact, we saw a decrease in the average frequency in which the “Alignment with Engineering Careers” and the ‘Transfer to Other Engineering Courses” codes were used. We did however see a few instances of “Broader Impacts and Social Context”, a *Critical Reflection* code that was not observed in the reports from the Control Cohort.

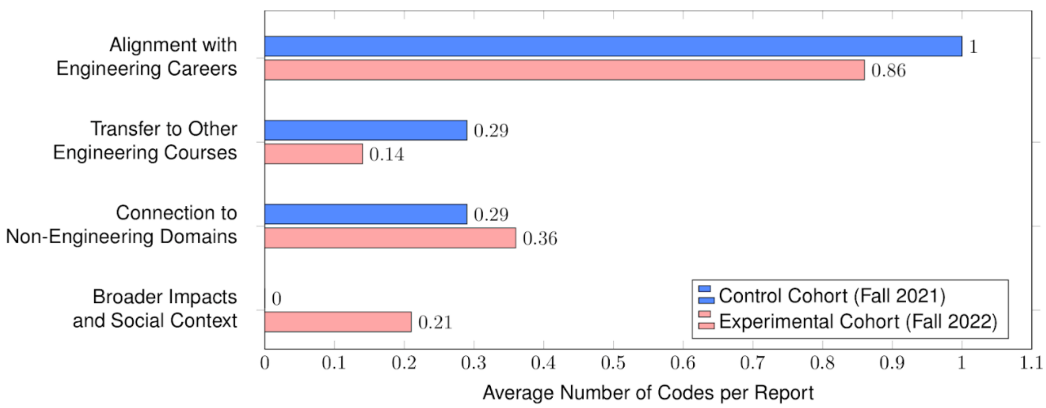

Figure 3: Average number of codes per report for each of the *Critical Reflection* codes

Discussion

Our results indicate a notable increase in students’ reflective thinking between the first and second years. The Experimental Cohort, having received the ePortfolio assignment their first year, demonstrated a higher volume of reflective comments overall, as well as a wider range in types of reflection. While the Control Cohort’s reflection assignments centered upon skills they learned in the lab assignment with a vague nod to the usefulness of these skills in their future engineering careers, the Experimental Cohort engages more in *Descriptive Reflection* (reflections on the process itself) and *Dialogic Reflection* (reflections on their personal engagement in the process). Surprisingly, there was little difference between cohorts in *Critical Reflection* (reflections and critical thinking about how the process relates to, or impacts, society) with only a few outliers in each cohort making specific references to the use of skills in non-engineering contexts or more broadly in society.

These results suggest that students are mirroring the faculty’s perceptions of good reflection. It is noticeable that our inductively-generated reflection codes yielded a high volume of codes that fell in the *Dialogic Reflection* category. The goal of the ePortfolio assignments in this department, therefore, is to develop students’ ability to tell personal narratives that help them build their engineering identities. Students’ ability to articulate their personal struggles, emotions, and limitations is valued highly by professors.

After discussion amongst faculty in the department, it was determined that *Critical Reflection* is emphasized less by the faculty in assigned materials. Students receive fewer prompts and activities to help them develop the knowledge and critical thinking required for this level of reflection, which may help explain its relative absence in these assignments. This may also be a consequence of the lab reports themselves, which may not require *Critical Reflection* since not all types of reflection are useful in all scenarios [6].

This study has several limitations. First, the sample sizes are small and therefore, caution should be exercised in applying the findings from this study to other contexts. There may be distinct differences in the type of institution, the small class sizes, or the way faculty teach reflection at this institution that significantly impact student outcomes. Second, the increase in reflection between cohorts may be a result of student personalities and cohort norms, which vary considerably by year. It is possible that the positive outcomes are an anomaly, and future research should verify this trend across multiple cohorts.

Conclusion

In this paper, we assess the impact an ePortfolio in a first-year design course had on students as they continued through the department's curriculum by coding lab reports from a second-year design course. To evaluate students' reflective abilities, we generated a codebook using inductive methods and then sorted our codes into the four different code categories identified by an established reflection method: *Descriptive Writing* (Not Reflective), *Descriptive Reflection*, *Dialogic Reflection*, and *Critical Reflection*. Since the ePortfolio assignment was recently introduced, we were able to compare a cohort of students that had not completed the ePortfolio assignment with the next cohort of students that was provided the ePortfolio experience. We discovered that students that had the ePortfolio experience in their first-year were more reflective thinkers in their second-year. The overall frequency of coded instances of reflection almost doubled for students that had the ePortfolio experience. The frequency increases were consistent across three of the four reflective categories, most noticeably in *Dialogic Reflection*. However, we were surprised that the students' tendency to practice *Critical Reflection* was not significantly impacted.

We conclude that this single ePortfolio exposure led students to be more reflective thinkers that better engage in reflection during subsequent technical courses. Reflection has broad potential to provide student benefits including stimulating metacognition, which improves students' ability to retain and recall information. We expect students that develop habits of reflective thinking will improve their ability to retain and connect core engineering concepts throughout the curriculum. Our future plans include continuing to expand ePortfolio usage throughout our department's curriculum and modifying our first-year ePortfolio assignment to try to evoke more *Critical Reflection* from students in order to further our understanding and promote our goal of cultivating reflective engineers.

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APPENDIX A

Code	*Code Description*	*Example of Coded Segment*
Descriptive Writing (Not reflective, reports events and processes)		
Learned a Skill	Felt the acquisition of the skill was important	This week I learned a lot about the different types of tools for assembling PCBs and how to properly connect and place components to make secure electrical connections that also keep the components in place.
Descriptive Reflection (Reflects upon the efficiency and effectiveness of their procedure)		
Evaluative Description of Work and Environment	Reflects upon their struggle and the impact of the work environment	One thing I struggled with was securing the components to the board so they would not fall out when I positioned the board for soldering. The crowded space also made it difficult. As a result, I did make some burn marks and less than ideal soldering applications on the back of the board
Evidence of Iteration and Non-Required Work	Additional actions were taken in the design process, above and beyond expectations, usually as a result of failed attempts	I started off with some soldering practice on some old damaged PCBs and then I used the manual solder paste nozzle to carefully apply solder paste to the Bucknell B PCB.
Dialogic Reflection (Reflects upon their personal performance, learning, and interests)		
Personal History	Links to their own past experience	In high school I wanted to create a LED strip that had different colors and displays for my room, but in order to do this you must know how to design a PCB and solder components. Now I feel like I have a good grasp on this and that project would be possible.
Personal Interest	Links to their intrinsic interest in the topic	I had a great interest in the physical components part of electrical engineering, but I never tried it. After this week's assignment, I realize I like this part of ECEG.
Emotional State	Indicators of emotional state during the activity	I found the empty PCB to be somewhat overwhelming at first, and it took a little bit of time to settle in and feel confident in each step I took.

Metacognition	Articulates the thought process they used to solve the problem, assesses what learning strategies worked and did not work	Although it was time consuming, I found this design assignment very interesting. In terms of the lessons this has taught me as an engineer, I have found that new skills can be picked up very fast if you apply yourself to understand and allow yourself the help of others, which was quite essential in this assignment.
Recognition of Deficiency	Reflection upon personal traits or lack of skill that contributed to struggle	I think it will take some time for me to hone my skills and become comfortable in using equipment in the Maker-E as well as general tools for applications of electrical and computer engineering
Desire for Expertise	Mentions a desire to further build skills in this area	I hope to become more proficient and more confident in the soldering processes by learning more advanced techniques.
Description of Collaboration with Others	Mentions working with others and how this impacted their learning	Having a buddy that you can check your work with and walk through the training really helped make this Design Assignment run smoothly and allowed me to learn more about PCB assembly due to sharing our knowledge
Critical Reflection (Reflects upon this lab's relation to the wider social context)		
Alignment with Engineering Careers	Mentions that this skill will be helpful in an engineering job	The process of printing a PCB, placing, and soldering components is hugely applicable to many things in ECE. PCBs are in just about everything in modern electronics.
Transfer to Other Engineering Courses	Mentions this skill will be useful in other engineering domains	It was meaningful to learn to solder and connect to ECEG 210, circuit theory and design. We use virtual PCBs in that class and it is nice to know how PCBs function in real life.
Connection to Non-Engineering Domains	Mentions this skill will be useful in other NON-engineering domains	Soldering is a skill that I can carry with me throughout my life and apply to my job as a Technical Assistant in the Theatre, creating circuits to accomplish tasks in the technical theatre space.
Broader Impacts and Social Context	Links to larger societal context & importance	While it is important to focus on things that can be great for society, the planet, or your wallet, taking some time to do creative things opens our minds and allows us to be better in every field. Creativity leads to new solutions to problems, and practicing different art forms, especially utilizing our learned skills, can change the way we approach problems in every aspect of our lives.